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An Assessment of Natural Base Solution Prepared from different Parts of *Musa sp*. as a Scrubbing Agent of CO_2 from Biogas

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Abstract—*The use of different alkaline chemicals in chemical absorption process is a common technique for the removal of CO_2 from biogas. The problem arises in the disposal of the used chemicals due to its toxic and environment unfriendly nature. Natural base solution prepared by ashing different parts of banana plant is a traditional practice amongst the rural communities of Assam. This paper reports the characterization and application of the natural base solutions so prepared as a CO_2 scrubbing agent from biogas and to alleviate the adverse effects of using chemical base. Three natural base solutions by ashing Banana pseudostem (BPS), Musa balbisiana peel (MBP) and Musa acuminata peel (MAP) with pH of 11.48, 12.77 and 11.63 respectively were prepared. Analysis showed that the potassium quantity in MBP ash is found to be slightly higher (228.40 mg/g) than in MAP ash (209.72 mg/g) and BPS (189.64 mg/g). The base solution with a pH of 12.77 could enrich the methane content of raw biogas sample from 56.9% to 86.3% in a single run thereby establishing the potentiality and applicability of natural base solutions for CO_2 scrubbing from biogas.*

Keywords*: Musa sp., Characterization, pH, Natural base solution, Biogas, CO_2 scrubbing*

1. INTRODUCTION

The rise in environmental pollution produced due to toxic chemicals is of great concern to date because of their carcinogenic and non-biodegradable properties [1]. Biogas is considered as a potentially effective and sustainable energy source. The composition of biogas typically a mixture of 45-60% methane (CH_4), 40-55% carbon dioxide (CO_2), and a small amount of other gases like hydrogen (H_2), nitrogen (N_2), hydrogen sulfide (H_2S), and ammonia (NH_3), ranging from hundreds to a thousand parts per million [2]. The methane in biogas is a high valued source of energy, while other components are impurities that pose major impediments to the commercial use of biogas [3]. Calorific value of biogas with CO_2 varies from 18.7 to 26 MJ/m^3 and that without CO_2 is between 33.5 to 35.3 MJ/m^3 [4]. Thus, removal of carbon dioxide and hydrogen sulphide from biogas will enhance the fuel efficiency which could serve as a source of immense energy that can be used effectively for different purposes like cooking, lighting, vehicle fuel and power generation [5]. There are numerous types of biomasses in the world which could be used for several purposes like biogas production, land filling etc. Banana contributes to 16% of the world‘s total fruit production and becomes the second largest food produced in the world [6]. At the time of harvesting, the average weight of banana plant is about 100 kg, out of which 50 kg corresponds to pseudo-stalks, 2 kg to rachis, 33 kg to fruits and 15 kg to leaves. The percentage of product loss due to size, contamination, handling, transport and storage is estimated at about 20% [7]. The lignocellulosic material can be used as a raw material for production of feedstock for producing biofuels and biochemicals [8], bio-sorbents and adsorbents [9], or enzymes and metabolites [10]. The proportion of the banana, which is wasted as peel is 18–20%. After harvesting the fruit, the part of the plant which are cut and wasted as pseudo stems exceeds to few hundred metric tons in the plantations.

From the environmental point of view, the banana peel can be used as bio-adsorbent of soluble contaminants, such as phenolic compounds [11], metals [12], and dyes [9]. It can also be used in the production of ethanol [13], production of biomass and metabolites of biotechnological interest [10], as well as for production of pectin [14].

Kolakhar or natural base solution made from pseudostem, rhizome and peel is a traditional ingredient and a popular food additive in Assam. This process includes production of antacid by filtering water through the ashes of a banana peel or pseudostem (the name derived from the local term of Banana-kol or kola). Khar or base solution made from *Musa balbisiana* Colla has the best quality out of all the variants present in north eastern region of India [15]. Other than its normal use as food additive in cooking, kolakhar has been used to treat various diseases and disorders. The tradition of villagers using kolakhar as soaps and detergent for washing clothes and shampooing hair is being practiced since a long time. Farmers use kolakhar to kill leaches and prevent their attack while working in leech infected fields [16].

Banana Peels are natural sources of potassium and the solutions prepared from its ash can have a very high pH. It has several advantages over other conventional bases as it is a naturally available alkali, is milder than and not as corrosive as NaOH or KOH, inexpensive, abundant and an environment friendly effluent. In this paper an approach has been made for characterization of banana peels, its part and its ashes to determine its ability as a scrubbing agent for the removal of CO_2 from biogas.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Biomass collection and processing

Banana pseudostem (BPS), *Musa balbisiana* peel (MBP) and *Musa acuminata* peel (MAP) were collected locally. They were washed to free from any contaminants and were cut into small pieces and kept in a hot air oven at 60°C for 24 hours for the removal of moisture. This made the materials dry and easy to grind. The dried materials were pulverized in a grinder into powder form and kept in a muffle furnace at 650°C for 8 hours to convert it to ash. It was calculated that 1g of grounded sample produced approximately 0.14 g ash.

2.1.2 Preparation of base solution

1 g of ash of BPS was added to 100 ml distilled water to make a solution. The solution was kept in a shaker at 150 rpm and 25°C for 45 mins. The solution was then filtered using a filter paper and the pH was measured. Similar procedure was followed for preparation of solution from MBP and MAP.

2.2 Characterization of biomass samples

The biomasses and their ashes were characterized by proximate analysis, pH determination, elemental analysis by flame photometer and EDX, and topographical analysis by FESEM.

2.2.1 Proximate analysis

The moisture, volatile matter, ash and fixed carbon content of the biomasses were calculated by proximate analysis. The procedure to estimate the amount of moisture and ash content was adopted from the National Renewable Energy Laboratory (NREL) protocol. American Society for Testing and Materials (ASTM) D 271-48 was followed for volatile matter determination. Fixed carbon was determined by difference from summation of moisture, volatile matter and ash content.

2.2.2 Field emission scanning electron microscopy (FESEM)

FESEM (*Make: Zeiss, Model: Sigma*) was conducted to study the surface morphology of the raw biomass and their ashes.

2.2.3 Elemental analysis

Energy dispersive X-ray spectroscopy (EDX) (*Make: Zeiss, Model: Sigma*) was used to analyze the elemental composition of the selected samples. The biomass samples were converted completely into ash by heating in a muffle furnace at 650°C for 6 hours and were kept in a desiccator to cool to room temperature. A spherical pellet of diameter 5 mm and height 1 mm was prepared with the help of a pelletizer for the analysis.

2.2.4 Estimation of sodium (Na^+), potassium (K^+) and calcium (Ca^{2+}) concentration

A Flame photometry (*Make: Systronics, Model: 128*) was used for estimation of the concentration of inorganic metal ions (Na^+, K^+ and Ca^{2+}). Group 1 and Group 2 metals are quite sensitive to Flame Photometry due to their low ionization enthalpies.

2.2.5 Measurement of pH

The pH of the prepared solutions were determined with the help of a digital pH meter (*Make: Mettler Toledo, Model: 30266889*).

2.2.6 Gas chromatography

Raw and treated biogas samples were collected in Tedlar® bags and immediately analyzed in a gas chromatograph (*Thermo Scientific Trace GC Ultra Gas Chromatograph, USA*).

3. RESULTS AND DISCUSSION

3.1 Proximate analysis of biomass samples

Table 1 shows the proximate analysis data of the biomass samples. As can be observed from the table, MAP has the highest moisture content of 13.62% followed by BPS (11.46%) and MBP (7.42%). Apparently, MBP had the highest ash content of 11.27% followed by BPS (9.79%) and MAP (8.56%). Interestingly, it has been observed that the natural base solutions of the biomass sample with the least moisture content showed the highest pH and vice versa as discussed in the subsequent section.

Table 1: Proximate analysis value of BPS, MBP and MAP. The abbreviation M denotes moisture, VM denotes volatile matter and FC denotes fixed carbon.

Biomass sample	M	VM	Ash	FC
BPS	11.46	73.62	9.79	5.13
MBP	7.42	77.60	11.27	3.71
MAP	13.62	75.63	8.56	2.19

3.2 Field emission scanning electron microscope (FESEM) images of raw biomass and their ashes

Figure 1 shows the FESEM images of the raw biomass samples and their ashes. It can be observed from the micrograph that the porosity and the surface area of the biomasses increase on conversion to ash which is anticipated to aid the release of ions into the solution.

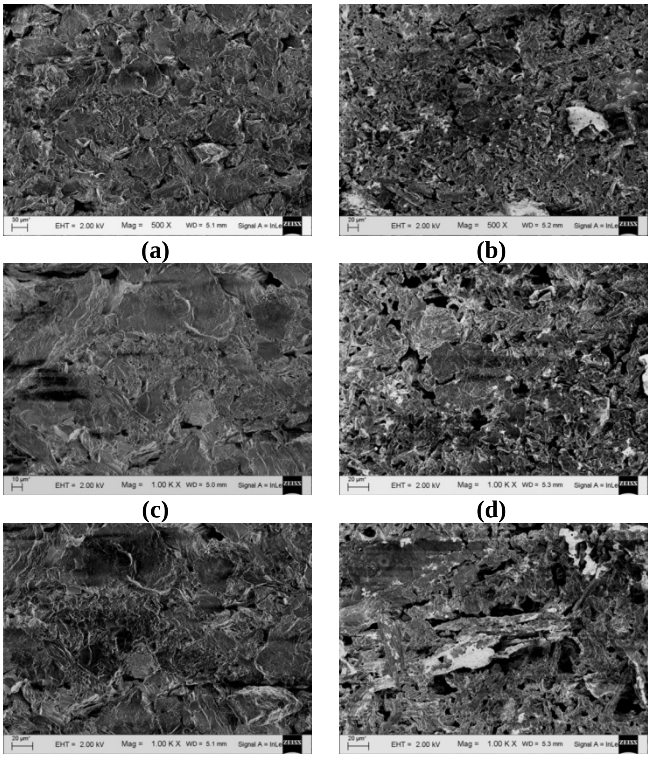

Figure 1: FESEM images of raw and ash samples of (a) Raw BPS (b) BPS ash (c) Raw MBP (d) MBP ash (e) Raw MAP & (f) MAP ash.

3.3 Composition of ash of biomass samples (wt%)

The composition of the elements presents in the ash samples of BPS, MBP and MAP were determined with the help of Energy dispersive X-ray Spectroscopy (EDX) and the results are summarized in Table 2. MBP ash has the highest potassium content (38.4 wt%) followed by MAP ash (34.2 wt%) and BPS (31.8 wt %). The finding is very encouraging as presence of K^+ ions would contribute towards increasing the pH of the natural base solutions. The percentage weight of calcium in the biomass ash samples are very low as compared to potassium; 4.4%, 1.3% and 1.7% for BPS, MBP and MAP respectively. The other elements P, Mg, Si, S, Mn, Al, Zn and Fe are also present but in trace amounts.

Table 2: Elemental analysis of ash samples of BPS, MBP and MAP using Energy dispersive X-ray Spectroscopy (EDX).

Component	BPS (wt%)	MBP (wt%)	MAP (wt%)
K	31.8	38.4	34.2
Ca	4.4	1.3	1.7
P	2.7	2.0	2.0
Mg	1.4	1.5	2.1
Si	1.0	1.4	1.5
S	1.0	0.7	0.4
Mn	-	-	0.2
Al	-	-	0.1
Zn	0.1	-	0.1
Fe	0.1	-	-

3.4 Elemental analysis in ash solutions

The concentration (mg/g) of the alkali and alkaline earth metals present in BPS, MBP and MAP ash solutions were determined with the help of Flame Photometer. As indicated by EDX analysis, flame photometry confirms potassium as the major cationic constituent in all the three samples (Table 3). The potassium quantity in MBP ash is found to be slightly higher (228.40 mg/g) than in MAP ash (209.72 mg/g) and BPS (189.64 mg/g). However, as expected the concentration of sodium and calcium were relatively low as compared to potassium.

Table 3: Alkali and Alkaline earth metal concentration of ash samples of BPS, MBP and MAP using Flame photometer.

Samples	K+ (mg/g)	Na+ (mg/g)	Ca2+ (mg/g)
BPS	189.64	0.66	1.974
MBP	228.40	0.0045	0.426
MAP	209.72	0.0017	1.34

3.5 Result of pH versus Ash Concentration

An experiment was conducted to assess the effect of ash concentration on pH of the solution prepared. 100 ml distilled water was taken in a conical flask to which 1g of ash was added and mixed properly. The initial pH of the respective base solutions were recorded as 10.96 for BPS, 11.39 for MBP ash and 11.04 for MAP ash. The process was repeated by adding 1 g consecutively until the pH stabilized. Figure 2 shows the values recorded for all the instances. From the graphs it was observed that the pH increased with increase in ash concentration (g) due to the formation of hydroxides, carbonates of alkali and alkaline earth metals and stabilized at a certain level. However, the highest pH recorded for each biomass ash were 11.48 for 8 g BPS, 12.77 for 10 g MBP and 11.63 for 8 g MAP.

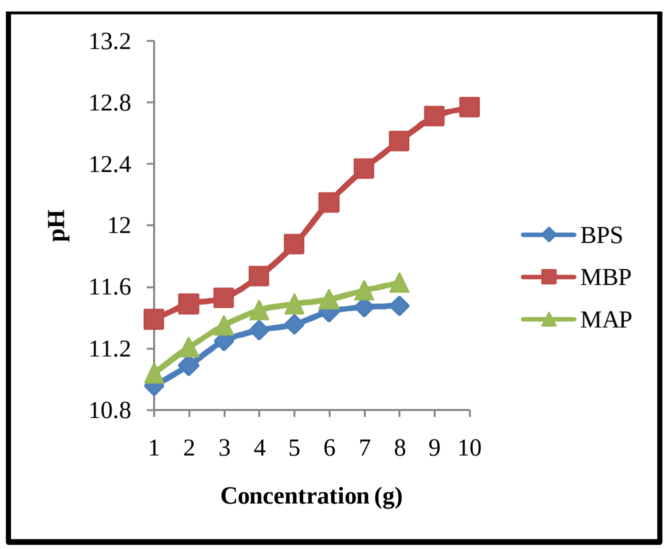

Figure 2: Comparison of pH Vs Ash Concentration graph of BPS, MBP and MAP

3.6 Methane enrichment in biogas on treated with Scrubbing agents

Natural base solutions prepared from the three biomass ashes *viz*. Banana pseudostem (BPS), *Musa balbisiana* peel (MBP) and *Musa acuminata* peel (MAP) were used as scrubbing agent for the removal of CO_2 from biogas. The methane percentage of raw biogas sample was 56.9%. When compared with the raw biogas sample, the treated biogas samples exhibited 19.9%, 29.4% and 21.5 % enrichment in methane when passes through base solutions prepared from BPS, MBP and MAP respectively (Figure 3). This proves the applicability of the natural base solutions as a CO_2 scrubbing agent from biogas.

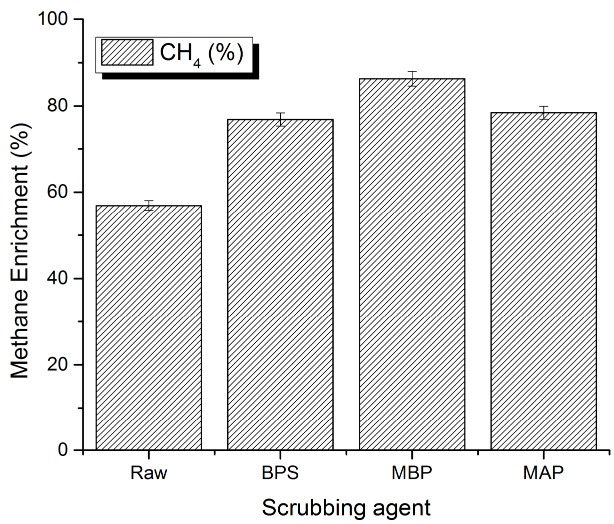

Figure 3: Methane enrichment Vs Scrubbing agents

4. CONCLUSION

This work reports the characterization and application of natural base solutions prepared from different parts of *Musa sp*. to be used as CO_2 scrubbing agent from biogas. The characterization by EDX, Flame photometer and pH meter reveals the presence of potassium in all the three biomass ashes in higher quantities as compared to the other elements. The natural base ash solution prepared from *Musa balbisiana* peel (MBP) had the highest pH of 12.77 and could enrich the methane content of a raw biogas sample by 29.4% followed by 21.5% (MAP) and 19.9% (BPS) which shows the potentiality and applicability of natural base solutions for CO_2 scrubbing from biogas. The team is currently working on design and fabrication of a scrubbing unit to enable complete removal of CO_2 from raw biogas sample and to increase their efficiency.

5. ACKNOWLEDGEMENTS

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